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Rule 312 Amendment

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1. (Currently Amended) A method of compensating for carrier frequency and phase errors of a received multi-carrier modulated (MCM) signal, said received ~~multi-carrier~~ MCM signal including data tones for transmitting data and training tones for error correction, comprising:

time-domain down-converting said received ~~multi-carrier~~ MCM signal to base-band to provide a down-converted signal, the down-converted signal including a plurality of data tones for transmitting data and training tones for carrier phase error correction;

sampling a training tone of the down-converted signal to provide received data samples;

providing a reference signal derived from the training tone of the down-converted signal; and

estimating phase errors from a phase difference between the training tone and the reference signal derived from the training tone of the down-converted signal to provide a plurality of received sample phase error estimates for each data tone,

wherein the estimating phase errors is provided by a first

tone tracking circuit for tracking each training tone and then calculating a phase angle of the training tone, and

wherein the first tone tracking circuit comprises a tone tracking mixer filter, a mixer, and a phase angle calculator.

Claim 2 (Canceled).

3.(Currently Amended) A method of compensating for carrier frequency and phase errors of a received multi-carrier modulation (MCM) signal, the received MCM signal including information-bearing data tones and known-reference training tones, comprising:

time-domain down-converting the received MCM signal to base-band to provide a down-converted signal, the down-converted signal including a plurality of data tones for transmitting data and training tones for carrier phase error correction;

time-domain down-converting each of the plurality of training tones to base-band to provide time-domain phase samples of each training tone;

providing a reference signal derived from the training tone of the down-converted signal;

estimating time-domain phase errors from a phase difference between the time-domain phase samples of each training tone and the reference signal derived from the training tones of the

down-converted signal to provide a plurality of time-domain received sample phase error estimates for each time-domain received data sample of the received MCM signal,

wherein the estimating time-domain phase errors is provided by a first tone tracking circuit for tracking each training tone and then calculating a phase angle of the training tone, and

wherein the first tone tracking circuit comprises a tone tracking mixer filter, a mixer, and a phase angle calculator;

coherently combining the time-domain received sample phase error estimates of each of the plurality of training tones to provide a single coherently combined time-domain phase error estimate;

applying the single coherently combined time-domain phase error estimate to the time-domain down-converted received MCM signal to compensate for MCM signal frequency and phase errors; and

frequency domain converting a compensated down-converted received MCM signal for further digital signal processing.

4. (Currently Amended) A method of compensating for carrier frequency and phase errors of a received multi-carrier modulation (MCM) signal, the received MCM signal including

information-bearing data tones and known-reference training tones, comprising:

time-domain down-converting the received MCM signal to base-band to provide a down-converted signal, the down-converted signal including a plurality of data tones for transmitting data and said training tones for carrier phase error correction;

time-domain down-converting each of the plurality of training tones to base-band to provide time-domain phase samples of each said training tone;

time-domain down-converting each of the plurality of data tones to base-band to provide time-domain phase samples of each data tone;

providing a reference signal derived from said training tones and data tones of the down-converted signal;

estimating time-domain phase errors from a phase difference between the time-domain phase samples of each said training tone and the reference signal derived from said training tones and data tones of the down-converted signal to provide a plurality of time-domain received sample phase error estimates for each time-domain received data sample of the received ~~multi-carrier~~ MCM signal; and/or

estimating time-domain phase errors from a phase difference between the time-domain phase samples of each data tone and the reference signal derived from said training tones

and data tones of the down-converted signal to provide a plurality of time-domain received sample phase error estimates for each time-domain received data sample of the received ~~multi-carrier~~ MCM signal;

coherently combining the time-domain received sample phase error estimates of each of the plurality of training tones and also of each the plurality of data tones to provide a single coherently combined time-domain phase error estimate;

applying the single coherently combined time-domain phase error estimate to the time-domain down-converted received MCM signal to compensate for frequency and phase errors; and

frequency domain converting a compensated down-converted received MCM signal for further digital signal processing.

5. (Previously Presented) A method of compensating for carrier frequency and phase errors of a received multi-carrier modulation (MCM) signal, the received MCM signal including information-bearing data tones and known-reference training tones, comprising:

demodulating the MCM signal to produce an initial set of MCM data decision estimates;

time-domain down-converting the received MCM signal to base-band to provide a down-converted signal, the down-converted

signal including a plurality of data tones for transmitting data and said training tones for carrier phase error correction;

time-domain down-converting each of the plurality of said training tones to base-band to provide time-domain phase samples of each said training tone;

time-domain down-converting each of the plurality of data tones to base-band to provide time-domain phase samples of each data tone;

providing a reference signal derived from said training tones of the down-converted signal;

providing a second reference signal derived from the initial set of MCM data decision estimates determined during an initial demodulation process; and

estimating time-domain phase errors from a phase difference between the time-domain phase samples of each said training tone and the reference signal derived from said training tones of the down-converted signal to provide a plurality of time-domain received sample phase error estimates for each time-domain received data sample of the received MCM signal; and/or

estimating time-domain phase errors from a phase difference between the time-domain phase samples of each data tone and the reference signal derived from the initial set of MCM data decision estimates determined during the initial demodulation process, to provide a plurality of time-domain received sample

phase error estimates for each time-domain received data sample of the received MCM signal;

coherently combining the time-domain received sample phase error estimates of each of the plurality of said training tones and also of each the plurality of data tones to provide a single coherently combined time-domain phase error estimate;

applying the single coherently combined time-domain phase error estimate to the time-domain down-converted received MCM signal to compensate for frequency and phase errors; and

frequency domain converting a compensated down-converted received MCM signal for further digital signal processing.

6. (Currently Amended) A method of compensating for carrier frequency and phase errors of a received multi-carrier modulation (MCM) signal, the received MCM signal including information-bearing data tones and known-reference training tones, comprising:

demodulating the ~~multi carrier~~ MCM signal to produce an initial set of MCM data decision estimates;

time-domain down-converting the received ~~multi carrier~~ MCM signal to base-band to provide a down-converted signal, the down-converted signal including a plurality of data tones for transmitting data and said training tones for carrier phase error correction;

time-domain down-converting each of the plurality of said training tones to base-band to provide time-domain phase samples of each said training tone;

producing refined time-domain phase samples of each said training tone by removing an estimate of the inter-carrier interference derived from both said training tones of the down-converted signal and the initial set of MCM data decision estimates determined during the initial conventional demodulation process;

time-domain down-converting each of the plurality of data tones to base-band to provide time-domain phase samples of each data tone;

producing refined time-domain phase samples of each data tone by removing an estimate of the inter-carrier interference derived from re-modulation of both said training tones of the down-converted signal and the initial set of MCM data decision estimates determined during the initial conventional demodulation process;

providing a reference signal derived from said training tones of the down-converted signal;

providing a second reference signal derived from the initial set of MCM data decision estimates determined during the initial conventional demodulation process; and

cstimating time-domain phase errors from a phase difference between the refined time-domain phase samples of each said training tone and the reference signal derived from said training tones of the down-converted signal to provide a plurality of time-domain received sample phase error estimates for each time-domain received data sample of the received MCM signal; and/or

estimating time-domain phase errors from a phase difference between the refined time-domain phase samples of each data tone and the reference signal derived from the initial set of MCM data decision estimates determined during the initial conventional demodulation process, to provide a plurality of time-domain received sample phase error estimates for each time-domain received data sample of the received MCM signal;

coherently combining the time-domain received sample phase error estimates of each of the plurality of said training tones and also of each the plurality of data tones to provide a single coherently combined time-domain phase error estimate;

applying the single coherently combined time-domain phase error estimate to the time-domain down-converted received MCM signal to compensate for MCM signal frequency and phase errors; and

frequency domain converting a compensated down-converted received MCM signal for further DSP signal processing.

7. (Currently Amended) A multi-carrier transmission system for carrier phase and frequency error correction comprising;

a multi-carrier modulation transmitter; and

a multi-carrier modulation receiver including a down conversion circuit and a training tone tracking circuit, the multi-carrier modulation receiver being coupled to receive a signal transmitted from the multi-carrier modulation transmitter, the received signal being applied to the down conversion circuit to produce a down-converted signal, the down-converted signal being applied to the training tone tracking circuit for correcting phase and frequency errors and producing a phase and frequency error compensated signal for subsequent demodulation at a training tone tracking circuit output,

wherein the training tone tracking circuit includes:

a training tone tracking PLL, where an input of the training tone tracking PLL is coupled to an output of the down conversion circuit,

a multiplier having a multiplier first input coupled to the output of the training tone tracking PLL, and a multiplier output coupled to the training tone tracking circuit output,

wherein the training tone tracking PLL includes:

a phase detector for receiving the down-converted signal at a first input of the phase detector and providing a detected phase error at an output of the phase detector, and

a carrier detector, having an input coupled to the output of the phase detector, and an output coupled to the output of the training tone tracking PLL, and

wherein the phase detector includes a tone tracking mixer filter unit, a mixer, and a phase angle calculation circuit.

8. (Previously Presented) The multi-carrier transmission system for carrier phase and frequency error correction of claim 7, wherein the multi-carrier modulation receiver is disposed as a digital circuit using digital signal processing techniques.

Claim 9 (Canceled).

10. (Previously Presented) The multi-carrier transmission system for carrier phase and frequency error correction of claim 7, wherein the training tone tracking PLL further includes:

a loop filter having an input coupled to an output of the phase detector; and

a frequency synthesizer having an input coupled to an output of the loop filter, and a frequency synthesizer output

coupled to a training tone tracking PLL output and to a second input of the phase detector.

11. (Previously Presented) The multi-carrier transmission system for carrier phase and frequency error correction of claim 7, wherein the training tone tracking PLL includes a second order phase locked loop.

12. (Previously Presented) The multi-carrier transmission system for carrier phase and frequency error correction of claim 7, wherein the loop filter is a first order loop filter.

13. (Previously Presented) The multi-carrier transmission system for carrier phase and frequency error correction of claim 7, wherein the training tone tracking circuit further includes:

a matching delay circuit wherein the matching delay circuit input is coupled to the training tone tracking circuit input.

Claims 14 - 16 (Canceled).

17. (Previously Presented) A multi-carrier transmission system for carrier phase and frequency error correction comprising:

a multi-carrier modulation transmitter; and

a multi-carrier modulation receiver including:

a down conversion circuit, and

a training tone tracking circuit,

the multi-carrier modulation receiver being coupled to receive a signal transmitted from the multi-carrier modulation transmitter,

the received signal being applied to the down conversion circuit to produce a down-converted signal,

the down-converted signal being applied to the training tone tracking circuit to correct phase and frequency errors and produce a phase and frequency error compensated signal prior to demodulating the phase and frequency error compensated signal,

wherein the training tone tracking circuit includes:

a training tone tracking PLL having an input coupled to a training tone tracking circuit input;

a matching delay circuit wherein the matching delay circuit input is coupled to the training tone tracking circuit input; and

a multiplier having a first input coupled to an output of the matching delay circuit, a second input coupled to the training tone tracking PLL output, and an output coupled to an output of the training tone tracking circuit,

wherein the training tone tracking PLL includes:

a phase detector having an input coupled to the training tone tracking PLL input;

a loop filter having an input coupled to an output of the phase detector; and

a frequency synthesizer having an input coupled to an output of the loop filter, and a frequency synthesizer output coupled to a training tone tracking PLL output and to a reference frequency input of the phase detector,

wherein the phase detector includes:

a tone tracking mixer and filter circuit wherein an input of the tone tracking mixer and filter circuit is coupled to the phase detector input;

a mixer having a first input of the mixer coupled to an output of the tone tracking mixer and filter circuit, and wherein a second input of the mixer is coupled to the reference frequency input of the phase detector; and

a phase angle calculation circuit wherein an input of the phase angle calculation circuit is coupled to an output of the mixer.

18. (Previously Presented) A multi-carrier transmission system for carrier phase and frequency error correction comprising:

a multi-carrier modulation transmitter; and

a multi-carrier modulation receiver including:

a down conversion circuit, and

a training tone tracking circuit,

the multi-carrier modulation receiver being coupled to receive a signal transmitted from the multi-carrier modulation transmitter,

the received signal being applied to the down conversion circuit to produce a down-converted signal,

the down-converted signal being applied to the training tone tracking circuit to correct phase and frequency errors and producing a phase and frequency error compensated signal prior to demodulating the phase and frequency error compensated signal,

wherein the training tone tracking circuit includes:

a training tone tracking PLL having an input coupled to a training tone tracking circuit input;

a matching delay circuit wherein the matching delay circuit input is coupled to the training tone tracking circuit input; and

a multiplier having a first input coupled to an output of the matching delay circuit, a second input coupled to the training tone tracking PLL output, and an output coupled to an output of the training tone tracking circuit,

wherein the training tone tracking PLL includes:

a phase detector having an input coupled to the training tone tracking PLL input;

a loop filter having an input coupled to an output of the phase detector; and

a frequency synthesizer having an input coupled to an output of the loop filter, and a frequency synthesizer output coupled to a training tone tracking PLL output and to a reference frequency input of the phase detector,

wherein the phase detector includes:

a plurality of phase error circuits having a plurality of phase error circuit inputs coupled to a phase detector input;

a summing junction circuit having a plurality of summing junction inputs coupled to a respective plurality of phase error circuit outputs;

a complex exponential circuit wherein the complex exponential circuit input is coupled to a summing junction output;

a mixer wherein a first mixer input of the mixer is coupled to a complex exponential circuit output, and a second mixer input of the mixer is coupled to the reference frequency input of the phase detector; and

a phase angle calculation circuit wherein a phase angle calculation circuit input is coupled to an output of the mixer,

and wherein an output of the phase angle calculation circuit is coupled to the output of the phase detector.

19. (Previously Presented) The multi-carrier transmission system for carrier phase and frequency error correction of claim 18, wherein each of the plurality of phase error circuits includes:

a tone tracking mixer and filter circuit wherein the tone tracking mixer and filter circuit input is coupled to the phase detector input;

a channel compensation circuit wherein an output of the tone tracking mixer and filter circuit is coupled to the channel compensation circuit input; and

an arctangent circuit wherein an output of the channel compensation circuit is coupled to an input of the arctangent circuit, and wherein an output of the arctangent circuit is coupled to the output of the phase error circuit.

20. (Previously Presented) The multi-carrier transmission system for carrier phase and frequency error correction of claim 19, wherein each of the plurality of phase error tone tracking mixer and filter circuits includes:

a first mixer wherein a first mixer input is coupled to the input of the tone tracking mixer and filter circuit and wherein

a second mixer input is coupled to a sinusoidal signal set to convert a desired tone, of a plurality of tones, disposed in a multi-carrier signal spectrum to a baseband frequency;

a second mixer wherein a first input of the second mixer is coupled to an output of the first mixer and wherein a second input of the second mixer is coupled to a decision data signal; and

a low pass filter wherein an input of the low pass filter is coupled to an output of the second mixer, and wherein an output of the low pass filter is coupled to the output of the tone tracking mixer and filter circuit.

21. (Previously Presented) A multi-carrier transmission system for carrier phase and frequency error correction comprising:

a multi-carrier modulation transmitter; and

a multi-carrier modulation receiver including:

a down conversion circuit, and

a training tone tracking circuit,

the multi-carrier modulation receiver being coupled to receive a signal transmitted from the multi-carrier modulation transmitter,

the received signal being applied to the down conversion circuit to produce a down-converted signal,

the down-converted signal being applied to the training tone tracking circuit to correct phase and frequency errors and produce a phase and frequency error compensated signal prior to demodulating the phase and frequency error compensated signal,

wherein the training tone tracking circuit includes:

a training tone tracking PLL having an input coupled to a training tone tracking circuit input;

a matching delay circuit wherein the matching delay circuit input is coupled to the training tone tracking circuit input; and

a multiplier having a first input coupled to an output of the matching delay circuit, a second input coupled to the training tone tracking PLL output, and an output coupled to an output of the training tone tracking circuit,

wherein the training tone tracking PLL includes:

a phase detector having an input coupled to the training tone tracking PLL input;

a loop filter having an input coupled to an output of the phase detector; and

a frequency synthesizer having an input coupled to an output of the loop filter, and a frequency synthesizer output coupled to a training tone tracking PLL output and to a reference frequency input of the phase detector,

wherein the phase detector includes:

a plurality of phase error circuits having a plurality of phase error circuit inputs coupled to a phase detector input;

a summing junction circuit having a plurality of summing junction inputs coupled to a respective plurality of phase error circuit outputs;

a complex exponential circuit wherein the complex exponential circuit input is coupled to a summing junction output, and wherein an output of the complex exponential circuit is coupled to the output of the phase detector.

22. (Previously Presented) The multi-carrier transmission system for carrier phase and frequency error correction of claim 21, wherein each of the plurality of phase error circuits includes:

a tone tracking mixer and filter circuit wherein the tone tracking mixer and filter circuit input is coupled to the phase detector input;

a channel compensation circuit wherein an output of the tone tracking mixer and filter circuit is coupled to the channel compensation circuit input; and

an arctangent circuit wherein an output of the channel compensation circuit is coupled to an input of the arctangent

circuit, and wherein an output of the arctangent circuit is coupled to the output of the phase detector.

23. (Previously Presented) The multi-carrier transmission system for carrier phase and frequency error correction of claim 22, wherein each of said plurality of tone tracking mixer and filter circuits includes:

a first mixer wherein a first mixer input is coupled to the input of the tone tracking mixer and filter circuit and wherein a second mixer input is coupled to a sinusoidal signal set to convert a desired tone, of a plurality of tones, disposed in a multi-carrier signal spectrum to a baseband frequency;

a second mixer wherein a first input of the second mixer is coupled to an output of the first mixer and wherein a second input of the second mixer is coupled to a decision data signal; and

a low pass filter wherein an input of the low pass filter is coupled to an output of the second mixer, and wherein an output of the low pass filter is coupled to the output of the tone tracking mixer and filter circuit.

24. (Previously Presented) A multi-carrier transmission system for carrier phase and frequency error correction comprising:

a multi-carrier modulation transmitter; and

a multi-carrier modulation receiver including:

a down conversion circuit, and

a training tone tracking circuit,

the multi-carrier modulation receiver being coupled to receive a signal transmitted from the multi-carrier modulation transmitter,

the received signal being applied to the down conversion circuit to produce a down-converted signal,

the down-converted signal being applied to the training tone tracking circuit to correct phase and frequency errors and produce a phase and frequency error compensated signal prior to demodulating the phase and frequency error compensated signal,

wherein the training tone tracking circuit includes:

a training tone tracking PLL having an input coupled to a training tone tracking circuit input;

a matching delay circuit wherein the matching delay circuit input is coupled to the training tone tracking circuit input; and

a multiplier having a first input coupled to an output of the matching delay circuit, a second input coupled to the training tone tracking PLL output, and an output coupled to an output of the training tone tracking circuit,

wherein the training tone tracking PLL includes:

a phase detector having an input coupled to the training tone tracking PLL input;

a loop filter having an input coupled to an output of the phase detector; and

a frequency synthesizer having an input coupled to an output of the loop filter, and a frequency synthesizer output coupled to a training tone tracking PLL output and to a reference frequency input of the phase detector,

wherein the phase detector includes:

a plurality of phase error circuits having a plurality of phase error circuit inputs coupled to a phase detector input;

a summing junction circuit having a plurality of summing junction inputs coupled to a respective plurality of phase error circuit outputs;

a low pass filter wherein the low pass filter input is coupled to a summing junction output; and

an arc tangent circuit wherein an output of the low pass filter is coupled to an input of arctangent circuit, and wherein an output of the arctangent circuit is coupled to the output of the phase detector.

25. (Previously Presented) The multi-carrier transmission system for carrier phase and frequency error correction of claim

24, wherein each of the plurality of phase error circuits includes:

a tone tracking mixer and filter circuit wherein the tone tracking mixer and filter circuit input is coupled to the phase detector input; and

a channel compensation circuit wherein an output of the tone tracking mixer and filter circuit is coupled to the channel compensation circuit input and an output of the channel compensation circuit is coupled to one of the plurality of summing junction inputs

26. (Previously Presented) The multi-carrier transmission system for carrier phase and frequency error correction of claim 21, wherein each of the plurality of tone tracking mixer and filter circuits includes:

a first mixer wherein a first mixer input is coupled to the input of the tone tracking mixer and filter circuit and wherein a second mixer input is coupled to a sinusoidal signal set to convert a desired tone, of a plurality of tones, disposed in a multi-carrier signal spectrum to a baseband frequency; and

a second mixer wherein a first input of the second mixer is coupled to an output of the first mixer and wherein a second input of the second mixer is coupled to a decision data signal

and an output of the second mixer is coupled to the input of the channel compensation circuit.

Claim 27 (canceled).

28. (Previously Presented) A method for correcting carrier phase errors of a received multi-carrier modulation (MCM) signal, the MCM signal including information-bearing data tones and known-reference training tones, the method comprising:

down-converting the MCM signal to provide a down-converted signal, the down-converted signal including: data tones for transmitting data, and training tones for carrier phase error correction;

down-converting the data tones to provide data tone phase samples;

down-converting the training tones to provide training tone phase samples;

deriving a reference signal from the data tones and the training tones; and

estimating sample phase errors from:

a phase difference between the data tone phase samples and the reference signal for a sample of the MCM signal, or

a phase difference between the training tone phase samples and the reference signal for a sample of the MCM signal, or

both a phase difference between the data tone phase samples and the reference signal and a phase difference between the training tone phase samples and the reference signal for the sample of the MCM signal.

Claim 29 (canceled).